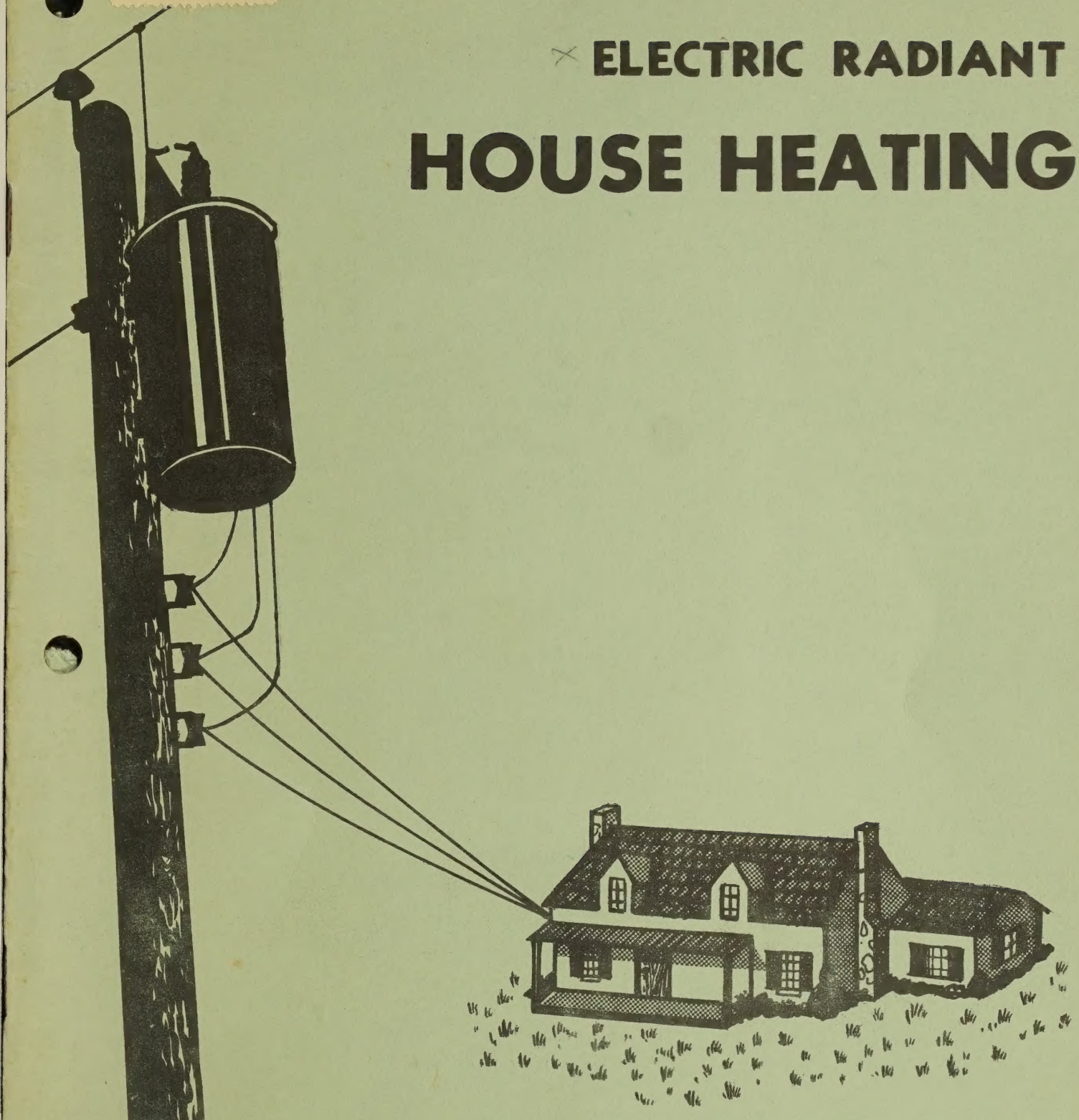
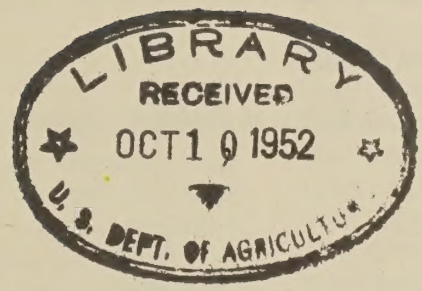
ELECTRIC RADIANT HOUSE HEATING



RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

ELECTRIC RADIANT HOUSE HEATING

Revised, July 1952



U. S. Department of Agriculture
Rural Electrification Administration
Technical Standards Division
Washington 25, D. C.

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ELECTRIC RADIANT HOUSE HEATING

TRANSFER OF HEAT

Electric heating equipment may be classified into two main classes as radiant or convection, or a combination of the two. To understand the characteristics of radiant heating equipment it is necessary to be familiar with the physical laws governing the transfer of heat.

Heat may be transferred in the following methods:

1. Conduction
2. Radiation
3. Convection

Heat may travel by either one, two, or three of the methods simultaneously or consecutively. Heat is conducted by means of molecular vibration; radiated by means of electro-magnetic waves and convected by the flow of currents in fluids (water and air).

CONDUCTION

Conduction is the transfer of heat between two bodies or parts of a body in direct contact with each other. This may be illustrated by heating one end of a metal rod and having the heat travel progressively to the other end of the rod. The heat is transferred by direct contact of one molecule to another within the material. Conduction occurs in solids, to some extent in liquids, and to almost negligible extent in air and other gases.

RADIATION

Radiation is the transmission of heat through a medium which occupies all intermolecular spaces. Radiant heat travels in straight lines until intercepted or absorbed by some body or object. It obeys the same laws as light; therefore, for all practical purposes, the transmission of pure radiant heat may be considered instantaneous. Radiant heat will pass through certain solid substances, such as glass, without heating them, and is reflected by various other materials. Radiant heat will pass through dry gases, regardless of their temperature, without heating them to any appreciable extent; however, air containing water vapor or dust will intercept and absorb radiant heat. Thus, the earth's atmosphere receives a part of its heat by radiation from the sun by virtue of the water vapor and dust in the air. Pure air will not intercept or absorb radiant heat.

All bodies above absolute zero temperature radiate heat. For a body to become warm it must absorb more radiant heat than it is emitting. When heat energy leaves the surface of the heat source, it is converted into long wave length rays. As soon as the rays strike a solid object, they are immediately converted back into heat energy and the effect of warmth is experienced by the receiving body. A good example of the effect of radiant heat is the difference of noticeable warmth of a person while standing in the sun or under the shade of a tree on a cold, sunny day even though the temperature is the same in both places. When standing under the tree the person feels colder than when in the path of the radiant heat from the sun.

CONVECTION

Convection is the transfer of heat by the actual flow movement of the medium heated. This type of heat may be illustrated by the conventional house heating system where the air around a heated radiator becomes warm, expands, and rises to be replaced by cold air. This sets up a circulation within the room. The circulation may also be produced by mechanical means. Convected heat becomes effective when the circulating air comes into direct contact with a cooler body and transmits heat by conduction to that body. In the case of a warmer body it is effective when it limits the dissipation of heat from that body.

FUNCTIONS OF A HEATING SYSTEM IN A HOUSE

The primary source of heat for human beings is the heat generated inside the body. The human body is a heat-generating unit adjusted so as to maintain a blood temperature of approximately 100°F as long as the physical functions of the body are normal. Therefore, the function of a mechanical heating system in the home is not to heat the body but to keep the material environment in such condition that the heat of the body will not be dissipated too fast for human vitality and well-being.

Heat energy is always transferred from points of higher temperature to those of lower temperature. Since this is true, the heating system warms the house and air, but it does not warm the body, since the temperature of the walls and air is lower than the surface temperature of the body which is approximately 85°F. Because of this difference in temperatures, the transfer of heat is out of the body and not inward. The house heating system is used to maintain the environment at a point so that a comfortable and stable body temperature can be maintained without the production of extra heat by the body which would cause discomfort.

TYPES OF ELECTRIC RADIANT HEATING SYSTEMS FOR HOMES

The various types of electric radiant heating systems known to be manufactured are:

1. Radiant Heat Panels
   a. Rubber panels
   b. Laminated wire panels
   c. Tempered glass panels
2. Heating Cable
3. Baseboard Heaters

The major types of electric radiant heating equipment, presently available, and a brief description of their construction and operation follow.

CONDUCTIVE RUBBER PANEL

USKON, manufactured by U. S. Rubber Company,* is a natural rubber to which has been added special materials permitting the conduction of electricity. There are no electrical wires within the panel other than the two aluminum foil potential leads to the conductive rubber layer. The rubber itself conducts electricity and provides the radiant heat.

The conductive rubber layer is sealed between two layers of insulating paper. The panels are in sheet form 1/16" thick. USKON comes in standard sizes of 3 X 4 ft., 4 X 4 ft., 4 X 6 ft., and also special sizes. The panels operate on 230 volts or 115 volts a-c, and are made with a wattage rating of 22 watts per square foot. Each room should be controlled and heated separately.

The manufacturer claims the panels will not exceed 100°F. with outside temperatures as low as 0°F., and for a panel operating continually, the surface temperature will not exceed 120°F. under any outside weather conditions.

USKON heating panels are connected in groups on parallel circuits. The total current carried by any one circuit should not exceed 20 amperes. The number of

*The firms mentioned in this publication may not be an exhaustive list of those manufacturing such equipment, and the fact that they are listed herein does not constitute an endorsement of any particular product. Prices quoted are as of July 1, 1952.

panels in any house or room depends upon the heat loss that has to be replaced to maintain the desired temperature.

USKON heating panels are installed on the ceiling. The panels are applied to plaster or wallboards with an adhesive furnished by the manufacturer.

The pattern of panels in a room should be placed to distribute the heat uniformly over the room area and form a simple attractive pattern pleasing to the eye. In small rooms of limited ceiling area, the panels are centered within the room. The entire ceiling of a room is not covered with panels except in extremely small rooms or in rooms with very high heat losses.

USKON panels are controlled by a standard low-voltage air-actuated or bimetal thermostat.

The price of the panel is approximately $1.10 per square foot. This does not include installation costs or the cost of the necessary control equipment.

USKON panels are approved by Underwriters' Laboratories, Inc.

LAMINATED RADIANT HEAT PANEL

Another type of radiant heat panel is made up of phenolic sheets which have a copper alloy wire heating element compressed between them and covered on the outside with aluminum sheathing. They are approximately .040 inches thick and are available in 46-, 58-, and 70-inch lengths which are 17 1/2 inches wide.

Each panel is complete with raceway section and terminal block for electrical connections. They operate on 240 volts and have a demand of 21 watts per square foot. The heat loss of the room will determine the number of panels needed and their spacing.

The operating temperature of the panels will average 110° to 120° F. They are controlled by a sensitive low-voltage thermostat in each room. An oil-base paint is used on the room surface of the panel as it increases the radiation factor.

The usual method of installation is to mount them on the ceiling plaster, sheet rock, plywood or other material with thin molding strips applied at the edges of the panels. They are spaced evenly and extend from each sidewall towards the center of the room. The raceway end is placed flush against the side wall and covered with a decorative molding.

GLASS HEATING PANELS

Radiant glass heating panels are manufactured by Continental Radiant Glass Heating Corporation, Appleman Glass Works and Berko Electric Manufacturing Corporation. The Continental and Appleman products are very similar in appearance, construction, and operation and consist essentially of three parts:

1. The heating element is a plate of tempered glass 16 X 24 in., approximately 1/4 in. thick, into which is fused a continuous aluminum alloy grid.
2. The glass plate is mounted in an aluminum reflector plate with an air space between it and the glass.
3. This unit is mounted in a steel frame with overall dimensions of 21 X 31 in.

The radiant glass heaters, models EH1B, EH1BB, EH4B, EH3B, EH3BB, and EH5B, offered by the Continental Radiant Heating Corporation bear the label of, and are listed by the Underwriters' Laboratories, Incorporated.

Electric current passing through the aluminum grid of the Continental radiant glass heaters raises the temperature of the grid and glass panel to approximately 340°F.

The aluminum reflector is placed between the glass panel and the back of the mounting frame. When the glass panel is above room air temperature, air from the room enters a horizontal opening beneath the glass panel. It passes vertically through the space between the glass panel and the aluminum

reflector and through the space between the aluminum reflector and the mounting frame. The air is thus heated and is discharged to the room through a horizontal opening at the top of the heater. The movement of air through the two passages and the reflective property of the aluminum reflector provides sufficient cooling to allow the radiant glass heater to be installed directly against combustible construction.

Room air also moves over the front of the glass panel by natural convection and is raised in temperature. The heating accomplished by the radiant glass heaters is a combination of convection and radiant heating since the glass panel, when at higher temperature than other surfaces in the room, also acts as a radiating surface.

The internal wiring of the radiant glass heaters is installed by the manufacturer and a junction box is provided on the back of the mounting frame for connection to the wiring circuit.

The radiant glass heaters are rated at 1000 watts on 115/230 volts a-c. This rating is on the basis of the stabilized current input after an operating period of approximately 20 to 25 minutes. The panels when first placed in operation will have an initial power demand of approximately 140 percent of the steady demand on continuous duty. The wattage decreases as the temperature of the panel increases until the panel reaches its normal temperature of approximately 340°F. Because of the high initial demand it is very important to consider the proper wire size and over-load protective devices for the circuits supplying the electric energy to the radiant heaters.

The maximum number of radiant glass heaters which may be operated on one thermostat on a-c depends upon the make and type of relay and also the service voltage provided. Four radiant glass panels is the maximum number that should be controlled by one thermostat.

Each room or heated space, or pair of spaces not separated by doors should be heated independently of all others. The radiant panels should be installed on external walls and under windows if possible. Radiant glass heaters should never be installed in the floor or ceiling. The upper edge of the mounting frame should not be more than three feet from the floor of the room.

The Continental radiant glass panels are priced as follows:

Wall panels
1000 watts
115, 208, 230, 240-255 volts. $59.50
625 watts
115, 208, 230 volts..... $54.50

Baseboard panels
450 watts
115, 208, 220, 230, 245 volts $51.00

These prices do not include controls, house wiring or installation.

The Appleman Glass Works wall panels are similar to the description given in the preceeding discussion. The sizes and list prices are as follows:

1000-watt
110 or 220 volts
without thermostat $57.65

600-watt
110 or 220 volts
without thermostat $43.25

1000-watt
110 or 220 volts
built-in thermostat..... $69.20

600-watt
110 or 220 volts
built-in thermostat..... $51.90

Appleman also manufactures a small wall panel rated at 250 watts. It measures 8 3/4 X 12 3/4 in. and is priced at $35.00.

The Appleman Glass Works has developed three new type panels which are designed for ceiling installation. One type is suspended from the ceiling on rods and is 16 1/4 X 24 1/4 in., 1000 watts, 110 or 220 volts. The list price is $57.65. The second type fits flush

against the ceiling and is 8 X 36 in., 500 watts, 110 or 220 volts. The list price is $48.00. Their surface temperature reaches 375° to 450°F. Both require a low-voltage thermostat, $10.50, and a relay, $15.50. The relay will handle up to 3 1000-watt units. A third type consists of a light and heating element combined in a circular ceiling fixture. The light is located in the center and is surrounded by a 500-watt glass heating element. A switch enables the user to turn on either the light, the heater or both. The price is $57.65.

The panels manufactured by the Berko Electric Manufacturing Corporation are made of Pyrex glass, the same as the others, 16 X 24 in. and 1/4 in. thick, and are mounted in a frame 20 11/16 X 27 5/16 in. They are rated at 1000 watts, 110, 208, or 220 volts. Other models are 23 1/2 X 27 5/16 in., 1000 watts, and a 600-watt size (110 or 220 volts) measures 15 3/4 by 25 1/16 in., both of which have a built-in thermostat. The entire back surface of the glass makes up the heating element. It consists of a thin electrically conductive coating, permanently fired to the glass.

It is claimed that the 110-volt panels have a slightly higher current demand when they are first turned on, whereas the 220-volt units operate at constant current. The glass reaches a maximum surface temperature of 375°F. in about 20 minutes. The unit has a wire grill guard. Transformer relays and mercury switches are available for controlling from three 1000-watt panels to as many as six 1000-watt panels. All models are approved by Underwriters' Laboratories, Inc. Other characteristics are similar to those which are discussed in relation to the Continental panels. The approximate list prices of the Berko wall panels are as follows:

1000-watt without thermostat	$55.00
1000-watt with built-in thermostat.....	$71.60
600-watt with built-in thermostat	$65.00

The Corning Glass Works manufactures several types of radiant glass panels as listed in table I.

Two of the conditions of acceptance listed by the Federal Housing Administration for their insuring offices are:

1. "Evidence shall be submitted that adequate electrical service will be provided by the electric utility company."
2. "The labeled voltage of the radiant glass heaters shall be within 5 percent plus or minus of the service voltage which will be provided by the electrical utility company for heating."

These are two of the requirements of Federal Housing Administration that have to be met before an FHA loan can be obtained by the home buyer , and may be of primary importance to some of the REA-financed systems.

TABLE I

Radiant Glass Panels Manufactured by Corning Glass Works

Glass Size (inches)	Mounted Size (inches)	Power Rating (watts)		Panel Temperature Degrees F.
		115V.	220V.	
12 X 12 X 7/32	13 5/8 X 13 5/8 X 1½	500		410
		1000	1000	536
		1500		644
16 X 24 X 7/32	17 5/8 X 25 3/8 X 1½	1000	1000	356
		1500	1500	428
			2000	527
			2500	599
			3500	

HEATING CABLE

Heating cable, manufactured by L. N. Roberson Company, called "Heatsum," and by Ceil Heat Division, Homes, Incorporated, called "Ceil Heat," may be installed in the ceiling, over existing ceilings, in wall plaster, and in concrete slabs or floors.

The "Heatsum" cable is approximately 1/8 in. in diameter, and has a plastic insulation. The "Heatsum" cable is laid in a sinuous arrangement; that is, it is laid as a flat coil with a definite spacing between turns. The spacing between turns depends on the heat loss from the room to be heated and the area of the surface to which the cable is to be applied. To determine the length of cable required to heat a room, the heat loss or heat load has to be calculated. This load is translated from Btu to watts. The correct length of cable is determined by the load in watts, and the cable installation is arranged so as to provide equal spacing to the applied surface.

Heating cable is available in a variety of sizes from 17-ft., 47-watt units for use on 120 volts a-c to 1036-ft., 2810-watt units for use on 240 volts a-c. The Company states that the cable is so designed that the maximum safe operating temperature of the cable insulation is approximately 167°F.

The "Heatsum" cable price varies with the length and wattage of the cable. A 17-ft., 47-watt cable costs about $5.30. A 1036-ft., 2810-watt cable costs approximately $61.80. The overall cost of this type of heating depends upon the amount of cable required, the thermostats and miscellaneous items, and the labor for installation. The adaptability of this type of heating equipment to old construction may prove uneconomical in most cases.

The "Ceil Heat" cable is a single-strand insulated heating element, which varies in length and wattage from 109 feet (300 watts) for 120 volts, to 1090 feet (3000 watts) for 240 volts. The price ranges from $7.30 to $37.90. The insulation, according to the manufacturer, is waterproof, has a high dielectric resistance, and will withstand temperatures up to 194°F. Other characteristics and installation methods are similar to those discussed with regard to "Heatsum" cable.

ELECTRIC BASEBOARD HEATERS

The Wesix Electric Baseboard heater, manufactured by the Wesix Electric Heater Company, is designed to be placed around the room at the location normally occupied by the wooden baseboard. The electric baseboards are constructed in sections from 2 ft. 8 in. to 4 ft. in length. The units are rated by the manufacturer at 105 watts per linear foot, and operate on 220 volts a-c. They are engineered to operate at a maximum surface temperature of 140°F.

Each section of baseboard contains two adjacent heating coils extending between terminal blocks at each end. It is equipped with knockouts on the end plates for connecting additional sections, and knockouts in the back for incoming service connections. As many sections of baseboards may be connected together in parallel as desired, within the safe limits of the electric circuit. Connections from the control equipment are made by running parallel circuits using the raceway area provided at the toe of the electric baseboard heater for the wiring.

The control section is 8 in. long and is designed to match the baseboard in appearance. It includes a thermostat and a double pole switch, and may be used up to a maximum capacity of 4000 watts. The baseboard sections may also be controlled by a wall type thermostat.

The retail price of the baseboard heater ranges from approximately $16.50 for the 2 ft. 8 in. section to $24.50 for the 4 ft. section. The control section is priced at $17.00. The number of sections required to heat a room depends on the heat loss and the size of sections used in the installation.

The Appleman Glass Works manufactures glass panel baseboards. They are made in the following sizes:

300 watts
42 in. long, 6 1/2 in. wide ... $34.00

200 watts
30 in. long, 6 1/2 in. wide ... $22.50

The baseboard units can be surface-mounted (usually done on old construction) or recessed. The surface temperature of the glass reaches approximately 240°F.

COSTS OF HEATING WITH DIFFERENT FUELS

To give a comparison of heating costs with different fuels, the following assumptions were made:

1. Btu loss per hour from the dwelling was assumed as 50,000.
2. The degree days were taken as 4,000.
3. Design temperature outside the home was taken as zero degrees F.
4. Design temperature inside the home was taken as 70 degrees F.
5. The various costs of fuels were assumed.

The computations were made according to procedures given in the Federal Housing Administration Bulletins, Heating Bulletin, MPR-Reference, paragraph 501-A, January 25, 1949, and Mechanical Engineering Bulletin No. ME-5, Special Heating Systems, August 1, 1949.

Table II sets forth the approximate cost of heating with different fuels.

The comparative costs of various methods of heating with different fuels in any area may be estimated by substituting the prevailing costs of fuels in that locality in the assumed cost per unit column and multiplying it by the estimated annual fuel consumption. The amount of fuel of any type required annually to heat any particular building will necessarily be governed by the heat loss which is dependent upon the construction of the building, degree days, design temperature, wind velocity and other factors.

GENERAL COMMENTS ON RADIANT HEATING

In designing an electric heating system, it must be remembered that one kwh of electricity can supply a maximum of 3413 Btu per hour of heat.

Electric radiant heat is 100 percent efficient, therefore 3413 Btu can be used in the calculations.

The Btu loss has to be calculated before any figures can be given on the kwh required to heat any house and maintain the desired temperature. The heat loss through the walls, windows, floors, doors, roof, etc., is the amount that has to be supplied by the electric heating system to maintain the desired temperature in the home. Consideration has to be given to these and the type of construction before recommendations can be made as to the type and number of electric heaters necessary for heating a building having a given number of cubic feet.

Various construction materials and combinations of these will allow heat to be lost from a house at different rates. Insulation and other means of reducing

TABLE II
COMPARATIVE HEATING COSTS

Coal
(Anthracite or High Grade Bituminous)

Method of Heating	Estimated Annual Fuel Consumption (tons)	Assumed Cost of Fuel per Ton (dollars)	Estimated Annual Fuel Cost (dollars)
Central system			
1. Stoker fired	3.66	$16.00	$58.56
2. Hand fired	4.39	16.00	70.24
Space heater			
Hand fired	5.49	16.00	87.84

Coal
(Low Grade Bituminous)

Method of Heating	Estimated Annual Fuel Consumption (tons)	Assumed Cost of Fuel per Ton (dollars)	Estimated Annual Fuel Cost (dollars)
Central system			
1. Stoker fired	4.76	$14.00	$66.44
2. Hand fired	5.72	14.00	80.08
Space heater			
Hand fired	7.14	14.00	99.96

Fuel Oil
(No. 1 and No. 2)

Method of Heating	Estimated Annual Fuel Consumption (gallons)	Assumed Cost of Fuel per Gallon (dollars)	Estimated Annual Fuel Cost (dollars)
Central system			
1. Oil fired unit	572	$ 0.10	$57.20
	572	0.12	68.64
	572	0.14	80.08
2. Conversion burner	602	0.10	60.20
	602	0.12	72.24
	602	0.14	84.28
Space heater or floor furnace	635	0.10	63.50
	635	0.12	76.20
	635	0.14	88.90

Gas
(100,000 Btu per Therm)

Method of Heating	Estimated Annual Fuel Consumption (therms)	Assumed Cost of Fuel per Therm (dollars)	Estimated Annual Fuel Cost (dollars)
Central system			
1. Gas fired unit	762	$ 0.08	$60.96
	762	0.10	76.20
	762	0.12	91.44
2. Conversion burner	878	0.08	70.24
	878	0.10	87.80
	878	0.12	105.36
Space heater, wall heater or floor furnace	878	0.08	70.24
	878	0.10	87.80
	878	0.12	105.36

Electricity

Method of Heating	Estimated Annual Kwh Consumption (kwh)	Assumed Cost per Kwh (dollars)	Estimated Annual Energy Cost (dollars)
Electric Panel Heaters	14,286	$ 0.005	$71.43
	14,286	0.01	142.86
	14,286	0.015	214.29

heat losses will contribute to greater living comfort and will also lower the costs of heating. It is strongly recommended that heat losses be restricted or reduced by all possible methods within practicability to obtain the highest efficiency justified by the saving and comfort produced.

Insulation should be placed in the ceiling regardless of the home location or the method used to heat the home. The savings in heating costs will usually pay for the original cost of the insulation within a few years and help to maintain a more even temperature throughout the house. Storm windows or double glass will reduce the heat lost through windows by approximately 50 percent. Where wall insulation can be installed during construction, the cost of insulation car usually be covered within a few years from reduction of heating costs. The cost of wall insulation in an old house may not be justified because the first cost cannot be covered during the life of the structure. The amount of insulation used has to be determined for each individual home on the basis of heat cost savings during the useful life of the structure.

PARTIAL LIST OF MANUFACTURERS OF

ELECTRIC RADIANT HEATING EQUIPMENT

Appleman Glass Works
Electriglas Radiant Heat Division
Bergenfield, New Jersey

Berko Electric Manufacturing Corp.
179-05 Jamaica Ave.
Jamaica 3, New York

Ceil Heat Division
Homes, Incorporated
Old Kingston Pike
Knoxville, Tennessee

Continental Radiant Glass Heating Corp.
1 East 35th Street
New York, New York

Corning Glass Works
Corning, New York

L. N. Roberson Company
1539 East 103rd Street
Seattle 55, Washington

United States Rubber Company
1230 Avenue of the Americas
New York, New York

Wesix Electric Heater Company
390 First Street
San Francisco 5, California